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Some Problems with Binary Features for Tone*

Herbert F. Stahlke
Georgie State University

1. Introduction

In this paper I will attempt one of the easier of linguistic tasks, that of falsifying a linguistic hypothesis without providing a better alternative. In this case, the attempt is not in the nature of taking a cheap shot since it focuses attention on problems inherent in a fundamental assumption of modern linguistic research, the tenet that phonological contrasts are to be described by binary systems. In particular, I will be arguing that the phonological representation of tone in binary features is inadequate for either synchronic or diachronic description. I will begin by reviewing the major feature frameworks for tone in use today, showing each to make incorrect claims for some languages, while correctly accounting for phenomena in others. I will then discuss data from Igede and Proto-Mixtecan, which show binary features to be formally unworkable.

I assume two criteria to be essential to any framework for describing the sounds of natural language. A phonetic theory of natural language must be capable of describing all of the phonetic contrasts found in natural languages and should exclude any sounds and sound-generating mechanisms which are not used in natural language. Thus it must include consonants involving a velaric ingressive airstream mechanism, but it must exclude sounds produced with an esophageal egressive airstream mechanism even though this is the normal airstream mechanism for persons who have undergone the surgical removal of the larynx. No natural language contrasts esophageal egressive and pulmonic egressive sounds. Secondly, phonetic descriptions must reflect at least the articulatory or the acoustic properties of the sounds of natural language and must do so in ways that reflect the classifications of sounds that are possible in natural language. Any phonetic theory which fails to meet at least these two criteria is inadequate as a phonetic theory of natural language.[1]

Linguists dealing with the phonological analysis of tonal languages have generally used one of four systems of representing tone levels. The oldest and perhaps most widely used of these treats a tone level as a point on a scale. This system is typified by Chao's (1930) system of tone letters (1), which distinguished five pitch heights.

(1) Chao's 'Tone Letters' (partial List) (1930)

Pitch	1	2	3	4	5
Letter	˥	˦	˧	˨	˩

Similar systems have been employed in American Indian languages, especially in the work of Pike and his associates (cf. Pike (1947)). Such scalar systems make no claims about the naturalness of tonal systems or of phonological rules for tone and hence have been neglected by generative phonologists in favor of binary feature systems. However, Chao's fundamental observation that no more than five levels of pitch are needed in the phonological description of any language has been incorporated into all binary systems for tone which have been seriously explored.[2] The three feature systems discussed in this paper have all used features defined in such a way that certain logically possible combinations, such as Woo's [+High Tone, +Low Tone], are excluded as being articulatorily impossible. That is, the features describe intersecting, rather than hierarchical, phonetic properties. In no system is there a feature which has the effect of raising or lowering any tone which the system can otherwise describe, thus doubling or quadrupling the number of phonologically necessary pitches in a language to ten or twenty. This is obviously a well-motivated limitation. I will assume, therefore, for purposes of discussion, that a feature system for natural language tone must account for five levels of pitch and will use intersecting, rather than hierarchical, features to do so.

2. Wang's feature system

The earliest set of features for tone to receive wide-spread attention is that proposed by Wang (1967). He proposed the features [±High], [±Central], and [±Mid], and argued for the following system.

(2) Tone features according to Wang (1967)[3]

Pitch	1	2	3	4	5
High	+	+	-	-	-
Central	-(U)	+(M)	+(M)	+(M)	-(U)
Mid	-(U)	-(U)	+(M)	-(U)	-(U)
Complexity	1	2	3	2	1

Wang's system makes the claim that the simplest and most natural tonal system will have two distinctive pitch levels, pitch 1 [+High, -Central, -Mid), and pitch 5 [-High, -Central, -Mid]. A

system of three tones would optionally include pitch 2 [+High, +Central, -Mid] or pitch 4 [-High, +Central, -Mid]. The implication of his markedness system is that a true mid tone would be found only in a system of at least four tones, since mid tone, that is, pitch 3, is more highly marked than either pitch 2 or pitch 4. It is not difficult to falsify this particular claim with African data. In Nupe (George (1970)), for instance, a syllable may have any of three tones on it, high tone (Wang's pitch 1), mid tone (Wang's pitch 3), or low tone (Wang's pitch 5). The fact that the middle tone must be [-High] is indicated by the fact that [+High] tones in Nupe become low-high rising when preceded by a low tone and a voiced consonant. The Nupe mid tone does not undergo this assimilation.

(3) èdu 'yam' Low-Mid
èbŭ 'cross' Low-High
èfú 'honey' Low-High
(George (1970:103-105))

The middle tone cannot be [-Mid], since there is a raised variant of low tone found in certain environments which is between low tone and mid tone.[4]

(4) u dà zã̀ dà → u dà: zã̀ dà [- - - _]
He walked walk
'He actually walked.'
(George (1970:120))

In Wang's framework, this tone would have to be specified [-High, +Central, -Mid]. This derived tone, however, is less highly marked than the distinctive mid tone, and thus Wang's framework makes an incorrect prediction for Nupe.

3. Woo's feature system

A system which would seem to work better for Nupe, as well as for many other African languages, is that proposed by Woo (1969). Her feature complexes for the same five pitch levels use the features [±High Tone], [±Low Tone], and [±Modify], as shown in (5).

(5) Tone features according to Woo (1969)

Pitch	1	2	3	4	5
High	+(M)	+(M)	-(U)	-(U)	-(U)
Low	-(U)	-(U)	-(U)	+(M)	+(M)
Modify	-(U)	+(M)	-(U)	+(M)	-(U)
Complexity	1	2	0	2	1

Woo's framework correctly predicts that Nupe alternation described above will be a natural alternation, as illustrated in (6).

(6) [+Low] → [+Modify] / __ [+Low] $\begin{matrix} n \\ 1 \end{matrix}$ # #

Her features seem to work well for many African languages, including Yoruba, Ewe, Igbo, and Bambara, to mention just a few. Woo faces difficulty, however, in describing a four-level system such as that found in Igede (Bergman (1971)). I will identify the tones by letters a-d, with a being the highest. Her marking scheme prevents a natural choice for the fourth tone, but it will require either that both middle tones be highly marked or that one be unmarked and the other highly marked. Igede exhibits four levels of lexical tone, as shown in (7).

(7) ɔ^{b} hʊ^{a} lɛ^{d} 'He has washed.'
ɔ^{b} hʊ^{b} lɛ^{d} 'He has stayed.'
ɔ^{b} hʊ^{c} lɛ^{d} 'He has scattered.'
ɔ^{b} hʊ^{d} lɛ^{d} 'It has flown.'
(Bergman (1971:16))

Igede also exhibits a number of complex alternations between tone levels. A final tone d on a verb becomes tone c before an object pronoun.

(8) kpɔ^{d} + ɔ^{c} → kpɔ^{c} + ɔ^{c}
satisfy him
(Bergman (1971:19))

All $CV^{c}CV^{c}$ verbs become $CV^{c}CV^{a}$ before object pronouns.

(9) bɪ^{c}rɪ^{c} + ɔ^{b} → bɪ^{c}rɪ^{a} + ɔ^{b}
spoil it
(Bergman (1971:19))

All $CV^{a}CV^{b}$ verbs become $CV^{a}CV^{a}$ before an object pronoun.

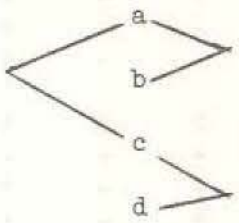
(10) kʊ^{a}rʊ^{b} + ɔ^{b} → kʊ^{a}rʊ^{a} + ɔ^{b}
cover it
(Bergman (1971:19))

Some CV^{c} verbs become CV^{a} before an object pronoun.

(11) do^{c} + ɔ^{b} → do^{a} + ɔ^{b}
abuse him
(Bergman (1971:19))

Thus Igede has d/c, b/a, and c/a alternations, as illustrated in (12).

(12) Igede tonal alternations



Since tones b, d and some instances of c raise before object pronouns, one would like to capture a generalization of tone raising, but such a generalization steadfastly resists formalization in features, as the following exhaustive list of possibilities illustrates.

(13) (i) Igede feature analysis I

Tone	a	b	c	d
High	+	+	-	-
Low	-	-	+	+
Modify	-	+	+	-

(ii) $CV^{d} \rightarrow CV^{c}$
$[-Mod] \rightarrow [+Mod] / [+\overline{Low}] + Pronoun]_{V}$

(iii) $CV^{b} \rightarrow CV^{a}$
$[+Mod] \rightarrow [-Mod] / [+\overline{High}] + Pronoun]_{V}$

(iv) $CV^{c} \rightarrow CV^{a}$
$\begin{bmatrix}+Low \\ +Mod\end{bmatrix} \rightarrow \begin{bmatrix}+High \\ -Mod\end{bmatrix} / \_\_ + Pronoun]_{V}$

Rules (13ii) and (13iii) could conceivably be collapsed using α variables, as in (14)

(14) $[\alpha Mod] \rightarrow [-\alpha Mod] / \_\_ + Pronoun]_{V}$

Even if no objection is made to the α-switching formalism, (14) is a most unusual way of saying that the tone of the verb raises before a pronoun. Other possible feature analyses for the four Igede tones are shown in (15).

(15) (i)

Tone	a	b	c	d
Pitch	1	2	3	4
High	+	+	-	-
Low	-	-	-	+
Mod	-	+	-	+

(ii)

Pitch	1	2	3	5
High	+	+	-	-
Low	-	-	-	+
Mod	-	+	-	-

(iii)	Pitch	1	3	4	5
	High	+	-	-	-
	Low	-	-	+	+
	Mod	-	-	+	-

(iv)	Pitch	2	3	4	5
	High	+	-	-	-
	Low	-	-	+	+
	Mod	+	-	+	-

The corresponding variants of (14) are shown in (16).

(16) (i) [+Mod] → [-Mod] / __ + Pronoun]$_V$

(ii) $[\alpha\text{Mod}] \rightarrow \begin{bmatrix} -\alpha\text{Mod} \\ -\text{Low} \end{bmatrix}$ / __ + Pronoun]$_V$

$\left\{ \begin{matrix} [-\text{Low}] \rightarrow [+\text{High}] \\ [+\text{Low}] \rightarrow [+\text{Mod}] \end{matrix} \right\}$ / __ + Pronoun]$_V$

(iv) [-Mod] → [Mod] / __ + Pronoun]$_V$

A comparison of (15) with (16) indicates that the simpler rules (16i) and (16iv) require the most complex feature analyses (15i) and (15iv), and the more complex rules (16ii) and (16iii) allow the less complex feature analyses (15ii) and (15iii). The relatively complex rule (14) requires the most complex feature analysis (13i). In none of the possibilities as (13iv) collapsible with the other two rules. What seems to be a relatively simple alternation in Igede cannot be described simply with Woo's features. The same is true of Wang's features, but the demonstration of that can be left as an exercise.

4. Maddieson's feature system

The third feature system for tone is that described in Maddieson (1971), using the features [±Raised], [±Lowered], and [±Extreme]. The features [±Raised] and [±Lowered] correspond directly to Woo's [±High Tone] and [± Low Tone], but [± Extreme] specifies unusually high or low pitches. Such tones are found often in the languages of Ghana, Togo, and Dahomey, for instance Avatime (Ford (1971) and Ewe (Westermann (1930)). The auditory impression of these tones is that they are indeed extreme high or extreme low tones, but this effect is not noted by Pike (1967) or Bergman (1971) for Igede, and seems in general to be unusual in the Kwa languages of Nigeria. The tones described by Maddieson's features are shown in (17). 1' and 5' indicate extreme high and extreme low pitches. Woo's feature [± Modify] is added parenthetically to indicate how the two systems could be merged. The markedness values have been added by the present writer and are not suggested in any way by Maddieson.

(17)

	1'	1	(2)	3	(4)	5	5'
Raised	+(M)	+(M)	+(M)	-(U)	-(U)	-(U)	-(U)
Lowered	-(U)	-(U)	-(U)	-(U)	+(M)	+(M)	+(M)
Extreme	+(M)	-(U)	+(M)	-(U)	-(U)	-(U)	+(M)
(Modify	-(U)	-(U)	-(U)	-(U)	+(M)	-(U)	-(U))
Complexity	2	1	2	0	2	1	1

While it may be the case that (17) represents a possible universal set of phonological features for tone, it is clearly no more adequate for Igede than is Woo's system. Maddieson's system by itself cannot describe pitches 2 and 4, pitches that are needed for Igede and Nupe, to mention only two cases. The combined system in (17) is inadequate also in that it predicts tonal systems of six and seven distinctive levels. No clear cases of such systems are attested.

5. Igede diachronic tone change

Not only does Igede present a problem for synchronic description, but it poses diachronic problems as well. The internal reconstruction of the contemporary Igede four-level system back to an earlier two-level system is relatively transparent. The four tones fall into three pairs of alternants, as shown in (12) above. Tones a and b alternate, b becoming a in CV^aCV^b verbs before an object pronoun; tones c and d alternate, d becoming c in all CV^d verbs before an object pronoun; and tones c and a alternate, c becoming a in all CV^cCV^c and some CV^c verbs before an object pronoun. This patterning suggests that in an earlier stage of Igede there were only two tones, a higher tone, which I will designate A, and a lower tone, which I will designate C. Each of these tones later split into a higher and a lower variant, a/b and c/d, respectively, resulting in the contemporary four-level system. The a/c alternation reflects an earlier stage in which the two tones A and C were realized as A in some environments. One case of this would have been the earlier reflex of the CV^cCV^c/CV^cCV^a alternation.

This reconstruction is supported by the tonal behavior of object pronouns. Verbs ending in reflexes of earlier tone A, now tones a and b, condition tone b on the pronoun.

(18) $ba^a + ɔ^b$ 'follow him'
$hɔ^b + ɔ^b$ 'affect him'
(Bergman (1971:20))

Verbs ending in reflexes of earlier tone C, now tones c and d, condition tone c on the pronoun. As noted above (8), tone d becomes tone c before an object pronoun.

(19) $kpɔ^c + ɔ^c$ 'satisfy him'
$ha^c + ɔ^c$ 'give to him'

The tone of the object pronoun is fully predictable and is sensitive only to a two-way tonal contrast--between the tones which I have designated A and C.

The splitting of A into a and b and of C into c and d presents a diachronic enigma directly paralleling the synchronic problem discussed in detail above. None of the binary feature systems presented earlier can offer a natural account of these diachronic changes, just as they were inadequate for a synchronic account. The development of such a two-way tonal contrast into a four-way tonal contrast is conceptually simple, but its description requires a framework in which a tonal spectrum divided into two ranges can be subdivided into four ranges. Such a description is not feasible in a binary framework, since binary systems predict natural tonal systems of two, three, or five levels. Systems of an even number of tones, where the number is greater than two, inevitably involve some kind of an asymmetric relationship between the tones, but the Igede tonal system of two pairs of alternating tones is not asymmetric.

6. Mixtecan diachronic tone change

The Mixtecan languages of Mexico (Longacre (1957)) exhibit tonal systems similar in some ways to those of Africa. Trique in particular has frequently been cited as an instance of a five level tonal system (Woo (1969)). However, the five levels of Trique and their correspondences in other Mixtecan languages present difficult problems for description in the feature frameworks presented earlier. Longacre (1957:103A) presents the following tone correspondences in Mixtecan languages.

(20) Tone correspondences in Mixtecan languages

Mixtec (San Miguel)		H	M		L
Mixtec (San Estaban)		H	M_1	M_2	L
Cuicatec		H	M		L
Trique	H_1	H_2	M_1	M_2	L

Longacre points out that in Trique and Mixtec (San Estaban) the pitch intervals between M_1, M_2, and L are much smaller than those between H and M. This follows from the fact that most M_2 represent lowered M_1. Trique H_1 arises consistently from a H_2 + /ʔ/ sequence, with the glottal stop deleted and the pitch level raised.

The Trique system cannot be adequately described by Woo's articulatory features, since H_1 and H_2 would have to be [+High, -Modify] and [+High, +Modify], respectively. The correspondences with other Mixtecan languages would then force the conclusion that the loss of final glottal stop after a high tone vowel resulted not in the raising of the high tone, a phenomenon which is well-attested in Asian and African tone languages, but in the lowering of all high tones not originally followed by a glottal stop. This is, of course, an intolerable consequence. Trique could, perhaps, be described by the framework in (17), specifying H_1 as [+Extreme] and H_2 as [-Extreme, -Modify], but this would only be an expediency. The phonetic effect of glottal closure is frequently a raising of adjacent pitches. Thus any of the three lower tones could also have been raised by the loss of a final glottal. That this did not happen does not provide support for such an analysis. What

weakens this analysis is the fact that extreme high tones in Kwa languages are not due to the loss of a final glottal. Thus tone raising conditioned by glottal constriction is not properly described by any of the features so far discussed.

Longacre (1957:93) also reconstructs a Trique noun suffix bearing a mid tone, tone 3 in a five-level system. His evidence for this is illustrated in (21).

(21) $yo^{3}{}^{?}o^{3}$ 'year' ~ $yo^{3}{}^{?}$ $ga^{3}c\underline{i}^{2-3}$ 'the past year'

$na^{3}k\underline{i}^{4}h\underline{i}^{4-3}$ 'atole' ~ $na^{3}k\underline{i}^{4}h$ $ru^{4}ne^{4-3}$ 'bean atole'

ka^{1-2} 'bone' ~ ku^{2-1} $a^{3}wi^{3}$ 'skull'

$te^{2}{}^{?}lo^{5}ho^{5-4}$ 'rooster' ~ $te^{2}{}^{?}lo^{5}h$ $l{\cdot}i^{3}h$ 'a little rooster'

gwi^{3} $\check{z}\underline{a}^{5-3}$ 'the eleventh day' ~ $\check{z}\underline{a}^{5}$ gwi^{3} 'eleven days'

$y\underline{a}^{3-4-3}$ 'salt' ~ $y\underline{a}^{3-4}{}^{?}u^{1-2}$ 'coarse salt'

gwi^{3-5-4} 'people' ~ gwi^{3-5} $za^{5}{}^{?}a^{5-3}$ 'nice people'
(Longacre (1957:77-78))

The phrase-final variants of the nouns, shown in the left examples in (21), all exhibit a shift towards tone 3. In positions other than phrase-final, the final tone disappears. He then posits an earlier Trique $-V^{3}$ suffix which was added to phrase-final nouns and later disappeared from Trique morphology, leaving behind only phonological alternations. This suffix still shows up as $-a^{3}$ in some Trique dialects. What is involved are the following tonal alternations on the final syllable of nouns.

(22)

sandhi form	phrase-final
2-1	1-2
4	4-3
3	3-3
5	5-4/3
3-4	3-4-3
3-5	3-5-4

In each case the tone glides one level closer to tone 3. Tones 3 and 4 glide to 3, and tones 1 and 5 glide to 2 and 4 or 3, respectively. If all tones glided to 3 or became 3, there would be no difficulty writing a rule for the change with binary features, but since the glide is not to a mid level but toward a mid level, a rule using binary features cannot express the proper generalization. An attempt at such a rule, using Woo's features, is given in (23) to illustrate the complexity involved.

$$(23)\ \left\{\begin{array}{l} [-\text{Mod}] \rightarrow [+\text{Mod}] \ /\ \left[\ \underline{\quad}\ \left\{\begin{matrix}[+\text{High}]\\[+\text{Low}]\end{matrix}\right\}\ \right] \\ \left\{\begin{matrix}\begin{bmatrix}+\text{High}\\+\text{Mod}\end{bmatrix} \rightarrow \begin{bmatrix}-\text{High}\\-\text{Mod}\end{bmatrix}\\ \begin{bmatrix}+\text{Low}\\+\text{Mod}\end{bmatrix} \rightarrow \begin{bmatrix}-\text{Low}\\-\text{Mod}\end{bmatrix}\end{matrix}\right\} / \quad \underline{\quad} \end{array}\right\} \begin{bmatrix}-\text{High}\\-\text{Low}\\-\text{Mod}\end{bmatrix} \begin{matrix}\text{N} & \text{(b)}\end{matrix} \qquad \text{(a)}$$

Condition: (a) and (b) are disjunctively ordered.

Rule (23) is clearly not a natural alternation, and yet the alternation it attempts to describe is conceptually simple. Its simplicity is obscured by the use of binary features.[6]

7. Conclusion

While it is obvious that binary feature systems for tone have permitted many important insights into tonal phonology, it is equally clear that a universal set of features must also include some formal devices to account for the phenomena found in Igede and Mixtecan. The data presented indicate three problems with binary feature systems for tone. In Igede the tones are clearly related to each other in a hierarchical fashion, illustrated schematically in (12) above. While it is certainly possible to describe hierarchical relationships with binary features, no tonal feature system adequate for a large number of languages is capable of doing so. The addition of raising or depressing features, which would be essentially diacritic in nature, would increase the number of possible distinctive tone levels for a language well beyond the five levels attested in natural language. At the same time, it is not clear that Igede requires a scalar, multivalued description. The behavior of the tones seems to be more hierarchical than scalar.

The Mixtecan tone correspondences involve a second problem of tone splitting. The conditioning factor for the split of Proto-Trique high tone into a raised high and the original high was the loss of a final glottal stop. Tone raising as a reflex of an earlier glottal stop is attested elsewhere in natural language (Maran 1972), but loss of the glottal stop in Trique results in tone raising only with high tone. Other tones may remain unchanged or even be lowered (Longacre (1957:83)), so one would hesitate to posit a phonological feature which described a raised variant of any tone. Not only would such a feature make incorrect predictions about Trique, but it would also predict tonal systems of up to ten levels, to say nothing of the sorts of phonological classes it would define. Present binary feature systems are inadequate to handle the raising of Trique high tone, and it is even not clear whether this change should be considered a split which produces a hierarchical relationship between tones, as in Igede, or whether it should be treated as scalar.

The third type of problem is the sandhi reflexes of the Proto-Trique $-V^3$ suffix. The phonological alternations illustrated in

(21)-(23) can only be considered scalar and so cannot be described by binary features in any natural way.

It is evident that some tonal systems in natural language behave in ways which are predicted by intersecting binary features. Others, such as in Igede, require strictly hierarchical binary features and cannot be described adequately with intersecting features. Still others, illustrated by Trique, require scalar features for at least some alternations. These facts present the phonologist with a serious question. Is it ultimately necessary to have non-unique phonetic theories such that a given language will be described in part by one theory and in part by another? If the answer to this question is even partially positive, the task of the linguist, to define the class of natural languages, becomes considerably more difficult.

Footnotes

*This paper is slightly revised from the version read at the conference.

[1]Obviously further criteria must be used to limit the class of phonetic theories, but I will not be addressing such questions as the acquisition or perception of language in this paper. The two criteria given are necessary, but not sufficient, to define a possible theory of natural language phonetics.

[2]I am excluding the system proposed by Gruber (1964), which describes only four levels. Gruber's system has not been tested sufficiently to determine what its properties are. For some discussion, see Fromkin (1972).

[3]I will not discuss the question of what the articulatory correlates of Wang's features might be.

[4]George (1970:119-120) gives very few examples of this and does not formulate a rule. (4ii) would probably need revision in the face of more data, but the revision would be in the environment.

[5]Bergman (1971:18) regards object pronouns as affixal.

[6]To complete (23) one would also have to allow for some pitch 5 to alternate with 5-3, and one would have to block a 2~2-3 alternation, since this is not attested.

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